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MANAGEMENT OF RECYCLED WASTE-PROCESS
WATER PONDS

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1. MANAGEMENT OF RECYCLED WASTE-PROCESS WATER PONDS

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Second Year of Study --
December 1, 1966 to November 30, 1967

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2. Summary Statement of Progress:

During the summer of the second year's study of Black and Decker Manufacturing Company's process water pond at Hampstead, Maryland, unusually cool, rainy, and stormy weather prevailed. These conditions, with the associated higher flow of storm waters into the process water pond, produced thermal stratification patterns substantially less marked than those prevailing during the previous series of hot dry summers. Silt turbidities were higher.

Work was completed on mechanical equipment for continuous sampling and monitoring of water quality through vertical profiles of the pond during stratification. Equipment for continuous sampling of treated waste influent, and process water return to the plant was installed, a flow recording flume was built into the pond influent channel, and special sampling points built into the improved domestic waste treatment system of the plant.

Standard electrical sensing systems were modified for water qualities of the process pond to provide continuous information on temperature, conductance, turbidity, pH, and dissolved oxygen to simple recording systems in the trailer laboratory. An improved method for determining nitrate in process water was developed.

Aquaria studies of population changes in stored process waters demonstrated the importance of zooplankters in achieving high organic removal efficiencies in stirred ponds.

Three public reports were presented and two papers were published.

3. Concise Statement of Progress

Management of Recycled Waste-Process Water Ponds
(Reuse of Treated Sewage for Manufacturing Process Water)

Report of Second Year's Studies under
Demonstration Grant No. WPD 117-02-67
Year Ending November 30, 1967

1. Purposes of Demonstration Grant Project:

This study was established to examine the biological, physical and chemical processes that take place in the waste fed process water pond of the Black and Decker Manufacturing Company at Hampstead, Maryland. The process water pond at this site is uniquely suited for the search for general principles that may be applied to water conservation and water quality improvement in water short areas that are otherwise fitted for industrial development.

The features of special value to the study are these:

(a) The system has evolved with plant growth over a period of 11 years, and there is a recorded background of water quality changes associated with plant activity, rainfall and storm flow, weather, waste water quality and flow, and pond management, so that a background of the factors producing quality changes has been established.

(b) The relatively simple mechanics of the pond input and outflows, together with well yield records and plant water consumption, make it possible to attempt materials and energy balance studies in a practical system.

(c) Black and Decker Manufacturing Company has been willing to join in a cooperative demonstration study, to permit access to the waste and process water systems, and to provide information to interested bodies. To this end, it has contributed substantial special facilities to the project, and has provided considerable active staff assistance.

(d) The reuse of treated domestic wastes and process waters for manufacturing and recreational needs is becoming more important in the practical development of water resources and in the preservation of special high quality waters.

2. Findings from Second Year Study:

(a) Effects of Weather and Rainfall
on Stratification and Water Quality
in Process Water Pond

The prolonged drought period in the Hampstead area came to an end in the late winter and spring of 1967. Flow of storm water through the collecting ditch surrounding the property, from the roofs and parking lots brought a continuous, unaccounted supply of fresh surface water into the pond, and produced almost continuous overflow at the dam. The spring and early summer temperatures remained low, strong to moderate winds prevailed, and there were few cloudless day. This contrasted strongly

with weather conditions during the first year of the study, when generally clear, dry, warm to hot weather prevailed.

As a consequence of wind, generally cooler temperatures, and decreased sunlight, and frequent storms through the summer, the waters of the process pond developed less extreme and sharp vertical thermal stratification patterns. Surface temperatures of the pond ranged from 6°C to 8°C below the 28°C to 32°C surface range of July to mid September, 1966. Temperature differences from top to bottom in the deep section (12.5 ft.) rarely exceeded 2.5°C in contrast to the 6°C to 12°C extremes observed in 1966. The effects of reduced surface heating were pronounced, too. The sharp rapid rise in temperature in the upper six to eighteen inches, characteristic of 1966 summertime, appeared only during a ten day clear warm period early in September, 1967.

The stratification patterns during late summer, 1967, were complicated by heavy flows of surface storm water bearing silt; these tended to move into deeper layers to produce temperature anomalies, deep bands with temperatures slightly above the overlying water. Settling of silt from these layers contributed to the instability of the water column.

Photosynthetic activity in the pond was not as pronounced as in 1966, though oxygen supersaturation; ranging from 20% supersaturation to 150% supersaturation was noted in the upper six to twelve inches. Generally, undersaturation prevailed below twelve inches from the surface. Zero oxygen was commonly recorded in the deep water during daytime intervals of stratification but there were no incidences of hydrogen sulfide production, and bottom mud was free of septic odors, except in shallow areas near the treated waste inflow.

The overall BOD removal efficiency of the trickling filter system and process water pond was high despite the cooler and generally less favorable weather. During the summer construction changes in the waste treatment plant were underway, but the plant itself was operated with surprising efficiency under the stresses of the conversion. BOD removal across the Imhoff tanks and trickling filter, with secondary settling, ranged from 40% to 55% during this interval. Combined removal of BOD in the treatment plant and process water pond ranged from 92% to 97%, an unexpectedly high rate of total removal under conditions that would normally be judged unfavorable.

(b) Development of Continuous
Sampling Equipment:

A major effort was made during the spring and summer of 1967 to establish programmed pumping equipment to deliver waste

water and process pond water to analytical instruments in the laboratory trailer for continuous monitoring of water quality. Through the cooperation of Black and Decker engineers, working under the supervision of Mr. James Woodward and Mr. Donald Hertz, and a special design team under the direction of Mr. James E. Taylor, engineering consultant to the study, a unique system of sampling devices was developed, installed, and brought into service. The total system permits continuous monitoring of the important water quality properties, and convenient selection of special samples for laboratory analyses.

The continuous sampling system consists of three parts:

- i. diversion of variable flow (up to 10 gpm) from the stream pumped from the pond to the Plant to a sampling pan at the trailer,
- ii. controlled pumping system delivering treated waste from the waste treatment plant outfall to a sampling pan at the trailer laboratory,
- iii. a timer controlled pump barge anchored over the deep portion of the pond and delivering samples from programmed depths to the sampling pan at the trailer laboratory.

These units were put in use and tested during the middle and late summer. Extended runs were made and a few changes made to provide reliable unattended operation. The combination promises to be extremely practical for our coming summer's program of studies, and some parts will undoubtedly be more generally useful in limnological, oceanographic, and water quality studies.

The vertical profile sampling barge is especially interesting in that it represents an economical combination of rugged, reliable equipment utilizing simple principles describing the daily development and breakdown of thermal stratification and water quality changes associated with it.

As developed by Black and Decker for the study, the vertical profile sampling barge is a covered sheet metal barge, 8 ft. x 8 ft. on which are mounted a positive displacement worm type pump, a small winch driven by a Geneva movement powered by a small gear-motor, electrical controls including timers, relays, and delay relays, micro-switches, and accessories necessary for control. In service, flexible suction hose with a slotted plate intake is lowered in steps by a cable fed from the winch. Water is pumped continuously to the laboratory; the quality varies with the position of the intake. (We found that practical intervals

for the conditions of our study to be six inch incremental changes in depth, each depth sampled for five minutes. In this way, a pump delivering 7 gallons per minute through a water hose approximately 350 ft. long, produce a well separated, thermally equilibrated sample of 21 gallons over three minutes of each five minute change period. Under extreme conditions approximately two minutes were required to reach thermal equilibrium in the delivery hose line. The three minute stable interval has proven adequate for oxygen electrodes come to equilibrium. Other measurements are less time critical, and large water samples may be collected for special studies without contamination by the electrodes of the field system.

When the flexible hose intake reaches the bottom (or any predetermined depth) by times steps, the winch automatically reverses and the intake is brought back to sample the top six inches again. In this fashion, it is possible to section the twelve foot water column of the pond in twenty four six inch increments each two hours of the day. The clocks and recorders of the laboratory are synchronized with the timer clocks and controls of the sampling barge, so that no special signals are required; the sudden shift in temperature and turbidity readily distinguish each cycle of the vertical sampler.

The vertical sampler contains a number of safety devices to prevent self destruction, to turn off the pump if it plugs or loses prime, to compensate for changes in pond level during dry weather, and to back up primary safety switches and relays; each mechanical control element is backed by an electrical equivalent. With the exception of the sampling increment, which is fixed at six inches by the design of the winch-Geneva movement combination, all other elements may be varied. Samples may be taken for any interval at any of the fixed depths; parts of the column may be explored as desired. Manual control is possible at the barge, and the design makes it possible to establish radio or wired wireless control from the laboratory.

This combination has performed very satisfactorily. Failures have not damaged the equipment and each incident has resulted in further improvement and simplification.

(c) Development of Analytical Methods
for Continuous Monitoring:

Parallel with the development of the continuous sampling system we have carried out studies of the modification of standard field systems of electrode analysis of water quality to fit the monitoring needs at the Hampstead process water pond. This was somewhat more

tedious than anticipated, but most difficulties have been eliminated (or understood well enough for control) and we are in good shape for favorable weather.

Our initial goal was to produce monitoring equipment that would run for at least a week without attention. This schedule would coincide with that now possible with simple clock driven recording meteorological equipment.

At present, our operations are more modest; light biological films that develop on surfaces of the oxygen electrode membranes and on the windows of light transmittance equipment, limit practical maintenance requirements to forty eight hours. This is not an inconvenience to our operation, removal of the films restores sensitivity with no readjustments and recalibration (for periods up to two weeks, and the enforced maintenance visits have other values.)

One built in advantage of combining the continuous pump samplers with the electrode monitoring is that the relatively steady flow rates produced by the pumps stabilize electrode conditions and yield more reproducible readings than we normally secure with equipment lowered by line.

We now have continuous monitoring equipment for dissolved oxygen concentrations, temperature, pH, conductance, and light transmittance. Our efforts to produce continuous turbidity measurements and selected pigments color absorption in continuous flow have been unsatisfactory because of interference by silt and fine gas bubbles.

In the laboratory the cadmium reduction method for determination of nitrate used for low concentrations in the marine environment has been adapted to conditions in the process water pond, and it appears that we will have a method that will permit the analyses of large numbers of samples for nitrite and nitrate without the usual troublesome and time consuming steps required by the phenoldisulphonic method. One improvement in the cadmium reduction method itself has been made. The extremely tedious step in preparing the granulated metal amalgam contact columns, normally requiring hand filing of stick cadmium, has been replaced by simple hydraulic sorting of fine commercial powdered cadmium. This yields sorts of uniform size which yield maximum interstitial volume in the column, controlled porosity, and excellent contact characteristics.

(d) Role of Zooplankton in Process Water Pond Purification:

The most useful and promising findings from the current year's study are those growing from observations on the grazing behavior of dense populations of cladocerans ostracods and other microscopic animals in aquaria of process pond water. The initial observations were fortuitous, but the preparatory conditions extend back seven years.

During early studies of the effects of modified air stirring schedules upon water quality in the Hampstead Plant process water pond, Black and Decker engineers observed that the color and turbidity of the pond varied sharply from day to day. An extended series of milipore filters through which daily samples of process water were passed showed sharp color changes from day to day, and the associated Secchi disc readings of the pond itself also showed wide variations -- but with little obvious relations to the color or density of pigment trapped on the filter face. No dominating pattern of change could be distinguished in the series of filters or in the Secchi disc readings; it could be noted only that the changes were sharp from day to day, and no general long term trends in color or color density could be demonstrated. Filters prepared on one day were straw colored, on the next green, on the next copper blue, the next straw or brown, etc. During this time explorations were being made with different times and intervals of aeration stirring, but these bore not relationships to the pigmentation on the filters.

Staff visiting the pond also remarked the changes in color and turbidity of the waters over short intervals.

In the late summer, a series of one gallon water samples were taken for transportation of the University laboratory. These were left through pressure of time on the counter tops of the trailer laboratory over the week end. An incidental glance at the samples before they were moved to transport showed that something had happened. The dense greenish turbidity that had distinguished the water at the time that it was taken had disappeared. The samples were now relatively clear and straw colored. And fine rusty specks, principally cladocerans, *Bosmina* swam around in the jars. The samples were now essentially impure cultures of *Bosmina*.

A series of simple batch aquarium tests were set up to check these observations. These, too, yielded surprising results. Gallon jars of pond water were stored in the trailer laboratory in the light and in the dark and population changes and turbidity (light transmittance) followed at interval through the working day.

Rates of changes from batch to batch varied widely, but the direction of change in the jars -- both in the dark and in the light -- was always the same; the zooplankters took over and grazed down the suspended phytoplankton algae. In many cases, the change was obvious to the eye within six hours; the regeneration of the phytoplankton population could not match the zooplankton predation in the closed system of the jars.

Samples green with *Euglena* and *Phacus* would turn straw colored with small cladocerans chock full of pigment overnight. More importantly, the bottoms of the jars were covered with settled fecal pellets and strings from the foragers; inorganic silt was also entrained in the strings.

In forty eight hours the foraging forms were noticeably more pale; their guts were empty, and the fecal strings were light. In four days to a week, with no additional feeding, most copepods and cladocerans in the foraging population had died and settled into the sediments on the bottoms of the jars.

These batch experiences with the mixed populations in the process water samples indicate that the pond water system must represent critical ratios of predators and producers. The population of grazing animals in the pond is, at any time, near the level of algal-plant production, and small changes in either population in this fertile, active environment shows within a short time in exaggerated shifts in the ratio at any sampling time.

The important consequence of this high grazing rate is the loss of energy and the immobilization of inorganic nutrients associated with the conversion of algal stuffs to grazing animal stuffs and detritus. The process is inefficient, and this is desirable for process water improvement. Carbon dioxide is lost to the water and to the atmosphere, nitrogen, phosphorus, and other nutrients fall to the bottom to be sequestered in the sediments.

In the past, we have been concerned with the larger animal life of the pond because they have appeared as nuisances in water delivered to the plant -- insect larvae, worms, snails, bryozoa and mussels. These are slow growing forms, with one or two life cycles per year -- or less. The zooplankton, on the other hand, have life cycles of a few weeks, and their capacity to saturate the grazing potential of the pond far exceeds that of the larger organisms.

3. Study Program for Third Year:

The observations on the high grazing rates in the process water pond raise several questions that are important in the management of such recycled waste water systems. We propose to seek answers to these and to describe our findings in terms that will permit reliable design and control of systems similar to that operated at the Hampstead site.

The first question that we wish to examine is related to stirring of the pond. It has been pointed out earlier that the process water pond at Hampstead Plant differs from the conventional sewage oxidation pond or lagoon in several features. First, it is fed clarified and partly treated waste. Second, it is mechanically stirred during the low light hours.

Although the total BOD loading of the pond is higher than most oxidation ponds, the effluent of the Hampstead Plant pond shows a lower BOD. The effluent is generally less turbid and colored than that of oxidation ponds.

Because the Hampstead Plant pond is thoroughly stirred every day, there is no deep, anaerobic layer of high solids content. Stratification, when it occurs, takes place only through thermal-density separation of the water layers.

Is it possible that (a) the elimination of a substantial anaerobic volume from the pond, and (b) the mixing of the water mass at short intervals, favors the production of a relatively large grazing zooplankton population? Can we produce this condition deliberately to secure the advantages of high rates of energy loss and nutrient sequestration?

We are now well prepared to follow the changes in water quality during stratification and breakdown of stratification in the pond. We can take samples of any volume from any depth that the quality data indicate.

Our program then will be to check out the impressions that have grown from the observations on population changes in the jar aquaria, to state these changes in quantitative terms, and to develop simple field methods make practical pond management possible.

It may be possible to describe changes in the ratio of predators to food producers by chemical methods -- as the ratio of chitin to chlorophyll or other pigment. But these analyses are not for field control of ponds. We would be interested to see if simplified methods such as the rate at which debris is thrown down in bottles of pond water or the six hour change in turbidity and color of stored samples

can be used as a practical indication of self purification rates in recycled ponds.

It is important also to examine the effects of temperature extremes, length of day, and other factors on the grazing population. It is to be anticipated that many recycled process water ponds will be used to capture and dissipate heat, so temperature optima and tolerance levels should be examined.

Finally, the action of toxic materials that may be encountered in wastes will be examined. These should include water conditioning agents, surfactants and coolants, metal complexes, insecticides, algicides, and similar industrial chemicals. Invertebrates and algae respond differently to many of these materials, and the presence of such materials may modify the performance of recycled waste-process water storage ponds.